DOCUMENT RESUME

ED 114 966 EA 007 707

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TITLE Contributions of Basic Sciences to Science of Education. Studies in Educational Administration.
INSTITUTION Andrews Univ., Berrien Springs, Mich.
PUB DATE Apr 75
NOTE 23p.

EDRS PRICE MF-$0.76 HC-$1.58 Plus Postage
DESCRIPTORS Biological Sciences; Education; Logic; Natural Sciences; Physical Sciences; *Problem Solving; *Sciences; Scientific Attitudes; *Scientific Concepts; *Scientific Methodology; *Scientific Research

ABSTRACT

The science of education has been influenced by the basic sciences to the extent that educational research now has been able to modernize its approach by accepting and using the basic scientific methodology and experimental techniques. Using primarily the same steps of scientific investigations, education today holds a place of much greater esteem than ever before. The methods of deductive and inductive reasoning are the basis of scientific inquiry, which has proved of extreme value not only to physical science, but also to the study of human behavior. There is no question that basic sciences like anthropology, biology, medical science, psychology, mathematics and statistics, and economics have helped make education truly a science. Indeed, without the knowledge of scientific methodology provided by these sciences, there would be no true research in the field of education. (Author)

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CONTRIBUTIONS OF BASIC SCIENCES TO SCIENCE OF EDUCATION

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April 1975

EA 007 207

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Introduction

We live in an era of awesome scientific discoveries and progress ranging from those which contribute to our health, welfare and pleasure to those which are capable of bringing about complete annihilation of mankind. Man has conquered, through scientific processes of problem solving, the sea and the sky, the space and the planets; and, indeed, he travels faster than sound and rides his dune buggy on the surface of the moon.

In the field of medicine, man has made spectacular discoveries both in prevention and cure of once uncurable diseases. There is hope for the cancer patient. Open heart surgery, heart transplantation, tiny pacemakers imbedded in man's bosom gives him a ray of hope for prolonged life. Man keeps on searching and researching into the mysteries of life hoping to find answers to many of his questions.

In the field of industry and technology the progress has been equally spectacular. New products are patented daily and are brought into market at an incredible rate. Man is capable of operating push button factories, and computers are capable of processing, in seconds,

data that would have taken a lifetime to work. The pace is rapidly increasing.

These discoveries, and inventions in medicine, social life, industry and technology have been almost totally obtained through the efforts of scientific research. The government and industry spend billions of dollars annually for scientific research and development. These benefits have been proportional to the outlay. However, these outlays have been mainly in the physical realm. Research in the social sciences has been slow and certainly has not matched the achievements in the material fields.

The achievements in the physical sciences took many years before they became significant; similarly, the success of research in social sciences will be equally slow.

Definitions

Before going more deeply into the topic, a pause to look at the definitions of the key words may be enlightening. What is science? What is basic science? What is the science of education? In the Dictionary of Education, Good (1959) offers the following definitions:

Science: Actively carried on as an effort to make the diversity of our sense experiences correspond to a logically uniform system of thought; in this activity experiences are correlated with a previously constructed theoretic structure of thought and understanding in an effort to make the resulting coordination in agreement with all observed properties or behavior.

Basic science: Basic science refers to general facts and principles that are fundamental to the study of specialized fields of science.

Science of Education: Science of Education refers to a systematical body of knowledge dealing with quantitative and objective aspects of the learning process; employs instruments of precision in submitting hypotheses of education to the test of experience, frequently in the form of experimentation.

Is Education a Science?

Can educators safely call education a science? There are four basic norms that establish a discipline as being a science.

The first is universalism. This norm, orientational rather than directive in its intent, refers both to the assumption that physical laws are everywhere the same and to the principle that the truth and value of a scientific statement is independent of the characteristics of its author. It is this principle that makes education an international community. For what an English educator discovers about early childhood education will be valid in the U.S.A. or Canada, and his work can be appreciated by educators everywhere. Empirical knowledge knows no national or international boundaries and to reject his findings for political reasons would be totally irrational vis-a-vis scientific goals.

The second norm is organized skepticism. This norm is directive, meaning that each educator should be held individually responsible for making sure that previous research done by others, on which he

bases his work is valid. Furthermore, he is obligated by this norm to make public his criticism of the work of others when he believes it to be in error. No contribution from any educator can be accepted without careful scrutiny, and that the scientist must question his own findings as well as those of others.

The third norm is communicability. This norm directs educators to share their findings with others freely without favor. For knowledge that is not in the public domain cannot be part of the legitimate body of knowledge against which creativity and productivity are measured and to which other educators refer in their work.

There is also the norm of emotional neutrality which enjoins the educator to avoid so much emotional involvement that he cannot be objective in his research.

Education has produced such men and women, and above all, education has borrowed from other disciplines to strengthen research methodology in its own realm. Hence, without fear of contradiction, one may speak of education as a science, or call it science of education.

History of Scientific Thinking

In the search for truth, man centers around five sources of evidence: (1) custom and tradition, (2) authority, (3) personal experience, (4) syllogistic reasoning from apparently self-evident propositions, and (5) scientific inquiry (Good, Barr, & Scates, 1935).

To a large degree, man behaves in a manner acceptable to his peers. This mode of behavior is necessary in part for men to live together. However, if custom and tradition are accepted as a justification for behavior it can stunt intellectual development. When man recognized his inadequacies in this area, the development of human thinking took a great step forward. The use of authority and personal experience has been quite common.

The first systematic approach to reasoning was through the use of syllogism. Aristotle introduced this method of deductive thinking. Syllogistic thinking established a logical relationship between a major premise (a self-evident assumption concerning a relationship), a minor premise (a particular case concerning one of the parts of the major premise's relationship), and a conclusion. Those who have studied logic will recognize the deductive reasoning of the following catagorial syllogism:

Fish cannot live on land.
Salmon are fish.
Therefore salmon cannot live on land.

A doctor uses deductive reasoning to discover his patient's sickness. Mathematicians use deductive methods in solving problems and have contributed greatly to the research scientists who use mostly inductive reasoning to reach conclusions (Lovell & Lawson, 1970).

Theoretical physics, like mathematics, is largely deductive; and yet contributions of men like Newton and Einstein to research in general have been enormous. Deductive thinkers have shown us the

way towards fairly close approximations to the truth by averaging and sampling which are crucial in the field of educational research. Bertrand Russell (1962) says this about the accuracy of science:

> Although this may seem a paradox, all exact science is dominated by the idea of approximation. When a man tells you he knows the exact truth about anything, you are safe in inferring that he is an inexact man. Every careful measurement in science is always given the probable error . . .

This is good news to the psychologist and educational researcher because by virtue of human variability of those he studies his result must at best be approximations of probability. How then, can anyone feel confident in putting months and years of work into a research project which by its very nature must be given as a generalized conclusion and may be proved wrong in succeeding years? The progress of other sciences through the centuries has taught mankind to accept the fact that one research study may trigger off another more accurate one, or perhaps a less inaccurate one. Consequently one's meager thesis might be regarded as one of the many steps in the direction of finding truth.

Although the beginnings of the scientific method, incorporating both deductive and inductive reasoning, are customarily assigned to the 17th century, it should be noted that Galileo made his famous experiment on the rate of acceleration of falling objects from the leaning tower of Pisa in 1589. Prior to that time natural phenomena were usually explained in terms of the supernatural.

Aristotle postulated that science is the knowledge of causes, using it in the modern sense of explanations. Francis Bacon, David

Hume, and J.S. Mills assumed that the job of the scientist was to establish universal propositions about causal connection. Indeed, in many basic ways, science is a search for the causes of certain kinds of phenomena. The necessary condition of cause makes what J.S. Mills calls the "invariable antecedent" in science. But that is not the whole picture. For if a scientist is concerned only with causal connection, his method becomes defective in general because of his lack of any systematic enumeration of possibilities (Encyclopaedia Britannica, 1971).

The scientific method involves a double movement of thought. One is a forward movement which goes from the particular to the general. It commences with facts and proceeds to develop a universal relationship which is generally expressed in a law, principle, or hypothesis. The second is the backward movement which commences with the general and moves toward a particular. Here, the researcher aims at proving a hypothesis through verification by testing the logical implications of the hypothesis.

Scientific Methods of Solving Problems

The researcher employs hypotheses in his work in order to guide his thinking process. According to VanDalen (1962) hypotheses are suggested problem solutions which are expressed as generalizations or propositions. The hypothesis is the tool the researcher uses to direct his search for knowledge, and to guide him in his selection and structuring of the facts to solve problems.

The importance of hypotheses in educational research, or for that matter, in any kind of research, cannot be overestimated. The researcher does not necessarily operate on a dream alone. After deep thought, he discovers some possible solutions to a given problem, as a result of efficient use of imagination and ability to see relationships. How many experiments, investigations and thorough analyses must be involved before a hypothesis is clearly formulated? Generally, once the problem is crystallized, then the real process of scientific investigation begins. The researcher should know what facts to compile, what methods to follow and what presentation of his findings to make. Gebhart and Ingle (1969) say that the hypothesis is the powerful launching pad that sets the whole scientific process into orbit, breathing hope and shedding light into a dark recess of the mind of man.

Hypotheses of course are not infallible. They are dependent on premises, operational definitions, and procedures of testing. Scientists as well as educational researchers must keep an open mind in this regard.

Steps of Scientific Research

Borg (1963, 1967) provides seven basic steps in scientific methods of problem solving. They are as follows:

1. Recognition of the problem.
2. Definition of the problem in clear specific terms.
3. Development of hypothesis.
4. Development of techniques and measuring instruments that will provide objective data pertinent to the hypothesis.

5. Collection of data.

6. Analysis of data.

7. Drawing conclusions relative to the hypothesis based upon your data.

Using the procedures of scientific inquiry as its base, educational research has developed its own methodology of experimentation. Good (1966) provides the following ten steps for educational research:

1. The decision to make an evaluative study.

2. Determination of the grade level at which to make it.

3. Selection of appropriate subjects.

4. Decision concerning the length of the period of time to be included.

5. Analysis of the content and the objectives if in rival programs.

6. Decision regarding the kinds of data to be collected.

7. Choice of available tests or other instruments, or the making of original tests or other instruments.

8. Determination of measures to assure equal quality of teaching or of means to allow for differences.

9. Selection of the statistical methods best suited for the treatment of data.

10. Final interpretation of findings.

Obviously, the basic sciences make their contribution in this process. Deductive logic allows the hypotheses to be arrived at; induction provides the method; mathematics helps correlate the data, and physics with some help from engineering provides the computer facilities which makes calculations easier.

Value of Scientific Methods

According to Borg (1963), the value of scientific method lies in developing theory and achieving knowledge so that the answers provided are sound and lead to real gains. Uncritical acceptance of authority opinion that is not supported by objective evidence has often led to ridiculous mistakes in the field of education. Borg (1963) points out that uncritical application of Freudian concepts to elementary school education led to some serious blunders in some of the "progressive schools" of the 1920's. Salesmen from educational enterprises have sold new programs such as modern math, PSSC Physics, BSCS Biology, Chem Study, etc. which educators accepted readily only to discard after they discovered that these programs have not done them any significant good. A valuable gain of scientific methods has been to avoid such mistakes. Currently, competency based education is being pushed upon the educational scene by politicians and salesmen alike and educators need to be on guard lest they accept a program without adequate research backing.

Common sense alone is not a sufficient guide to spend millions of dollars on new programs. The Arthur (1930) study of sixty first-grade repeaters showed that the average repeater did not learn more in two years than the average nonrepeater of the same mental age group. This, along with other studies like Sandin's ( ), refuted the "common sense" policies of the time. Currently many studies are being conducted in mathematics, science, guidance, and in other areas of

the science of education. Some of these studies are trivial but some are potentially very useful. With varying degrees of success, educators are using tools of basic sciences to discover the unknown in the science of education. Thus, one of the greatest advantages of employing scientific methods of solving problems is the opportunity of challenging authority opinion which has not been supported by evidence (Borg, 1967). It is further a method of challenging concepts which previously were applied to education without adequate research and consideration of long range effect.

An important condition of scientific method is that results are verifiable by other investigators (Garry and Kingsley, 1970). Thus the results become independent of the experimenter. As stated earlier, the scientific method minimizes reliance on personal experience for arriving at solutions to educational problems.

The Goals of Science and Research

Generally, science leads to an understanding of natural events. The aim of science is to discover new and useful information in the form of verifiable data. In science as well as in educational research one seeks to understand phenomena, to go beyond the factors underlying the patterns, to place phenomena in a large scheme of things. Good, Barr and Scates (1935, 1941) point out:

> When one is able to understand the uniformities of nature and offer satisfactory principles of explanation, one's knowledge is complete, comprehensive, and scientific.

Educational research should be directed toward collection of a scientific body of knowledge, which permits the researcher to discover generalizations of behavior. These generalizations are used to predict behavior in educational situations. They allow one to control behavior by planning procedures and practices. They help teachers to choose the right teaching and learning methods and materials.

Specific Contributions of Basic Sciences to the Science of Education

Education as a science is multidisciplinary in nature; as such, it encompasses many areas and draws resource material from several fields. Here we are concerned with the specific contributions basic science has made to education.

Mathematics and Statistics. Scientific research requires the use of objective measurement. The measuring tools used in education are much less objective than those in the physical sciences. This is due partly to the immaturity of the science of education and partly to the lack of initiative on the part of many educators to follow scientific methodology in problem solving.

In using measuring tools the procedures need to be standardized. Tools should be used only if they are reliable and valid for the purpose for which it is intended to use them.

Emphasis on the collection and analysis of data demanded by the scientific method, according to Garret (1964), has created a need for a systematic method of interpreting the evidence. The educational researcher collects volumes of evidence; evidence he will use to accept

ject hypotheses (Borg, 1967), to discover basic truths or principles, to establish relationships or test theory. According to Garret (1964), numerical evidence may be assembled from research situations concerning all characteristics of people, places, times, and things. But numerical evidence in itself is not sufficient; it must be interpreted scientifically. Here is where statistics comes to the aid of the educational researcher by providing the basic tools of analysis and interpretation of raw data (Borg, 1967).

Statistics are of two types: descriptive and inferential. Descriptive statistics involve tools that describe the nature of the sample group under study. Inferential statistics provide the tools of generalizing differences and relationships. Correlation techniques are used in studies involving relationships, prediction, and selection.

Here is a summary of the value which the science of statistics has for educational research.

1. It provides a sense of proportion or distribution of properties, traits, or scores by such means as equations, graphs, normal curve, curve-linear relationships as well as direct and indirect relationships.

2. It provides opportunities to make approximations and measure variations in certain phenomena. Some commonly used techniques are measures of central tendency such as the main, median, and mode. Others are the measure of variability such as variance or probability which permit researchers to predict with certain accuracy further occurence of certain phenomena.

3. It provides a sampling procedure. It is possible to apply mathematical probability theory to estimate whether or not a certain sample of the population is really representative of the general group or the population at large. In sampling, the researcher may consider the standard error and standard deviation in reference to the normal curve or the normal population distribution. The discovery of the normal curve and its properties (Brown, 1970) has helped the research worker to analyze data in terms of spread, thus contributing greatly to prediction and probability.

4. Statistics provide meaningful comparisons to the educational researcher. Scores from one research can be compared with those of another, or the scores of one project can be repeated to find out how valid the research has been and express this in terms of coefficient of correlation.

Mathematics, with the aid of engineering and electronics, has developed one of the most widely used tools in research--the computer. Furthermore, it has devised methods of programming the computer in order to perform at complex statistical calculations. Undoubtedly such methods have contributed to modern educational research by making it much more rigorous, discriminating and dependable (Rummel, 1964).

Anthropology. Anthropologists have contributed much to the understanding of people by pointing out cultural influences on the development of personality. Their studies have brought an awareness of the effects of different cultures of different countries and of regional cultures within a single country. They have shown the importance of

socioeconomic status as a factor in understanding the person. Anthropology, by pointing out the effect of culture on values, attitudes, and ideals, clarifies how a culture helps shape development. Main contributors in the field of Anthropology are such scholoars as Ruth Benedict (Patterns of Culture), Ralph Lintan (The Cultural Background of Personality), and Margaret Mead (Growth and Culture).

Biology and Medicine. Biological research has brought an awareness of the influences of heredity factors and together with medicine has led to findings on the effects of the control of hormones and vitamins on the development of children. In recent years medical science has done considerable work in the area of early childhood development as well as in the area of special education. Early diagnosis of learning disabilities has proven to be of great benefit to hundreds of children. Medical research is also responsible for helping physically handicapped children and for the increasing use of drugs in treating psychological disturbances of children.

It has been found that educators working cooperatively with biologists and medical scientists have offered significant help to thousands of children, who otherwise would remain ignorant. This interdisciplinary approach is highly recommended in dealing with any form of learning disorders children may have.

Psychology. Psychology has made a major contribution to the field of child study through its development of theories of human behavior and techniques for measuring individual differences. Psychology

has helped educationists draw richly on their understanding of such principles as intelligence, motivation, emotion, and learning. This has helped a great deal in designing curricula and development of appropriate teaching methods to make the educational situation a more viable entity. Psychology, for example, has taught educationists that I.Q. differences between boys and girls are small enough to be considered unimportant, that tests do not measure some aspects of mental activity but must be considered as samples of behavior; that a single intelligence test score does not predict a mental-growth pattern; that intelligence is subject to fluctuations related to a child's personal-social experiences and emotional life to mention just a few.

Sociology. Sociology has made its contributions by focusing on the importance of the social situation in which behavior develops. Sociologists have taught educators that the relationship between child and adult is crucial to effective motivation--there must be opportunities for the child to give as well as receive love, that mutuality and belonging can be utilized to change the child's capacity to function, that the family atmosphere, family constellation and the culture are all influential in the formation of the child's life style, that development of responsibility plays a major role in the development of personality.

Philosophy. Philosophy has helped the science of education in developing theories and educational models. Educationists have been affected by different viewpoints. Philosophic models have helped

them place educational phenomena in perspective; helped them follow the design of a research study or some practical recommendations in their fields.

For example, mechanistic theory, which received great impetus from Descartes, has found its most sophisticated modern expression in information theory which describes educational phenomena in the language of digital computers. The information theory model is helpful and has given educationists such concepts as feedback, signal-to-noise ratio and reverberating circuit. Feedback consists of a yes or no response; signal-to-noise ratio specifies how clearly information stands out from the background, and reverberating circuit accounts for "information storage."

Technology. Technology has influenced the science of education with such components as programmed instruction, which has raised new possibilities and problems which, in a world still starved of education and training, can hardly be ignored. Technology has also brought to the science of education multiple materials for research and varied tools in audio-visuals.

Colban says, "A computer technology is beginning to appear which permits almost anyone who is doing intellectual work, whether he is designing appliances or investigating history to have very cogent machine help available to him, minute by minute. This man-machine collaboration is a radical new tool of thought and may be comparable to the invention of writing itself in what it does to the manner in

which people think. Just as general literacy has made rote memory a fairly unimportant skill, so information-processing machines seem likely to assume most of the intellectual burden of strictly logical analysis, leaving intuition and imagination as the valued elements in human thinking."

Political Science. The science of Education is influenced by Political Science which catalogues the major political and legal facts that impinge on education as well as bringing into clear relief the role played by such extraneous factors as race, prejudice, and religion.

Economics. Economics plays a major role in the viable management of an educational system. The cost of education and research is soaring while the productivity in education continues to decrease. This makes it necessary to take economic factors into account. Certainly there is no excuse for doing a given job in an expensive way when it can be carried through equally effectively with less expenditure. Cost estimates should include not only direct expenditures for materials but also salaries and overhead, even those which are not directly charged to the project. Many educationists are quite unaware of the magnitude of overhead costs and are shocked when they see such figures. Overhead costs include rent, heat, electricity, administrative expenses of laboratory, gymnasium, auditorium, and salaries. Cost also enters in the decision whether to buy a piece of apparatus or to build it, where to build a school and of what design.

Geography and Architecture. Geographical and Architectural Sciences make their contributions in that they provide a compendium of information on land forms, climate, vegetation, residential and industrial patterns as well as the distribution of national and human resources. All these influence the locality and type of educational setting to be provided.

Guidance. Although the guidance movement has grown from a fledgling venture to the point where it is seeking admission to the family of traditionally recognized professions, it has its contributions to make to the science of Education. Guidance helps educators to develop student initiative, responsibility, self-direction, and self-guidance. It also helps the student to know himself, to recognize, understand, and solve his problems, to choose his personal and career goals wisely, to acquire insights and techniques necessary for making an effective contribution to society, and to develop ethical character so essential in the fostering of human relations and international understanding.

Conclusion

The science of education has been significantly influenced by the basic sciences to the extent that educational research now has been able to modernize its approach by accepting and using the basic scientific methodology and experimental techniques. Using primarily the same steps of scientific investigations, education today holds a place of much greater esteem than ever before.

In this paper it has been shown that the methods of deductive and inductive reasoning are the basis of scientific inquiry, which has proved of extreme value not only to physical science, but also to the study of human behavior.

Scientific thinking begins with facts and continues to return to facts to test and verify its hypotheses. The real motive which spurs the true scientists is consuming curiosity to find the truth (Good, 1963).

There is no question that basic sciences like Anthropology, Biology, Medical Science, Psychology, Sociology, Mathematics and Statistics, Philosophy, Technology, Political Science, Economics, Geography and Architecture, and Guidance and Counselling have contributed very significantly to help make education truly a science. Indeed without the knowledge of scientific methodology provided by these sciences, there would be no true research in the field of education.

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